Mechanical Degradation Pathways of Thermoresponsive Microgels under Ultrasonic Cavitation

Anindya Chowdhury, Georgios Papoutsidakis*, Walter Richtering**

** Institute of Physical Chemistry (IPC), RWTH Aachen University, Aachen, Germany*

chowdhury@pc.rwth-aachen.de

Ultrasonic cavitation generates intense, localized mechanical stresses that drive irreversible structural changes in soft polymer networks. While degradation of microgels under ultrasound is known, a clear mechanistic link between network state, architecture, and degradation pathways remains unresolved. Here, we investigate thermoresponsive PNIPAM-based microgels under high-intensity ultrasonication, focusing on how temperature-controlled swelling and core–shell architecture govern their response.

Microgel structure is tracked as a function of sonication time and temperature using dynamic light scattering (DLS), small-angle X-ray scattering (SAXS), small-angle neutron scattering (SANS), and atomic force microscopy (AFM). We observe a staged degradation process: at early times, the hydrodynamic radius decreases due to removal of loosely crosslinked chains at the periphery, while the network remains largely intact. With continued sonication, accumulated stress leads to network rupture, increasing structural heterogeneity and partial fragmentation. The degradation pathway is strongly governed by the swelling state, with swollen microgels highly susceptible to damage and collapsed microgels exhibiting enhanced stability.

For PNIPAM–PNIPMAM core–shell microgels, the degradation pathway depends on the swelling state of the core and shell. Distinct degradation behaviors emerge depending on whether each component is swollen or collapsed, reflecting changes in network stiffness and mechanical response. These results establish a direct link between microgel softness, architecture, and cavitation-driven degradation, providing a framework for controlling the mechanical stability of soft colloidal systems.

Keywords:
Microgels; Cavitation; Degradation; Scattering; Core–shell